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COTTON PRODUCTION FOR THE NEW MILLENNIUM



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Cape Town, South Africa, 9-13 March 2003

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Cataloging in Publication Entry

World Cotton Research Conference (3rd: 2003: Cape Town, South Africa)

Proceedings of the World Cotton Research Conference-3:

Cotton production for the new millennium: Submitted papers. Cape Town, South Africa, 9-13 March, 2003.

Chief editor: A. Swanepoel

1. Cotton – Research – Conference

I. Swanepoel, A. (Annette)

Printed in Pretoria, South Africa, May 2004.

Publisher: Agricultural Research Council - Institute for Industrial Crops

Layout and design: D.Comm

Print: D.Comm

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Risk assessment in decision-making using the COTONS® model

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ABSTRACT

Off-station experiments carried out in the framework of adaptive research and development programs, are generally limited by technical, human and/or financial considerations. The number of experimental sites needed to represent the environmental conditions variability of the cotton production areas, can be prohibitive. The major experimental designs carried out for adaptive research purpose, are usually not relevant for risk assessment associated with research and out-reach crop management recommendations. The cotton plant model COTONS® allows researchers to assess yield response to various crop management sequences and environmental conditions. These conditions include soil hydraulic characteristics and daily climatic data (solar radiation, rainfall, minimum and maximum temperatures and wind speed). This environmental data is complemented by soil fertility and cultural practices applied to the crop (variety, plant population, fertilization, plant protection etc.). This paper presents a probability-based approach to assess the risk-associated in decision-making under the various environmental uncertainty using COTONS®. Using this approach, model users are better informed of the risk and cost related to their decision making such as when and how much to apply fertilizer and/or pesticides. According to the proposed approach, daily decision rules for better crop productivity are based on crop state variables, i.e. cultivation techniques, application of additional N, and plant protection, etc. These rules resulted from a simulated data set corresponding to 396 environmental conditions and four crop management sequences. The risk assessment for a specific yield target is calculated as one minus the probability of exceedance the desired yield target level. The output of the risk-based approach for selected decision rules and crop management sequences are summarized in probability of exceedance plots. The plots allow the user the choice of the level of risk they choose to use and the probability trends for each decision rule. An economic cost evaluation of the different strategic options in crop management is also presented. The above approach allows for the assessment of the risk for different cotton crop management sequences. Application of the proposed approach may reduce the risk of obtaining the lowest yields for a certain condition. The COTONS® plant model was demonstrated as a powerful re-

search tool for improved and more informed decision-making.

Introduction

Each season, farmers take strategic planning decisions for their cropping system. They select the crops to grow on their different fields, order the set-ups for these different crops and plan the crop-field management sequences. Cotton producers take also day-to-day and short-term decisions in managing their cotton fields by scheduling their crop and selecting the type of cultivation operations. Generally, the farmer's attitude in decision taking is based on experiences and without any risk quantification.

On the other hand, the research development and the adaptive research programs are supposed and aimed to aid farmers in their decision taking. These decision aids are provided to farmers by local extension services. They are results of off-station experiments carried out at different soil and climatic conditions. However, the number of experimentation data sets needed to represent the variability of site and environmental conditions and to assess the risk associated with each recommendation, are generally limited by technical, human or financial resources. As result, most of decision-taking aid provided to farmers lack the consideration of risk assessment.

Due to the high interrelationship and effect of the site and environmental variability on the plant response under the different cropping management, quantification of this variability using probabilistic methods will lead to better and more informed decision making. Towards this goal, this paper proposes a probability-based modeling approach for improved decision-making, which allows for risk assessment in the technical outreach information provided to the farmers.

Experimental procedure

The COTONS® model (Jallas *et al.*, 1999) is a physiologically detailed simulation model of the growth and the development of the cotton plant system. It is an offspring of the GOSSYM model (Baulch *et al.*, 1995). To initialize and run COTONS®, the user provides inputs related to environmental descriptors of soil hydrologic characteristics, soil carbon and nitrogen contents, daily climatic variables (temperatures, solar radiation, rainfall and wind speed) and descriptive variables of crop management sequences (cultivar, dates and characteristics of cultural practices). Using this information COTONS® is able to simulate the growth of the crop during the cropping season. The plant model is coupled with the SIMBAD insect model (Nibouche *et al.*, 2002), which simulates plant damages resulting from bollworms attacks. At the end of the simulation the COTONS-SIMBAD system provides the outputs re-

lated to organs mass and number, plant topology and plant status indicators.

During the simulation the user can visualize the dynamic of plant growth on the computer screen. The COTONS-SIMBAD system was used to simulate growth and yield of cotton plants for 396 environmental conditions corresponding to the combinations of four soil types, three fertility levels during a 33 years weather period. All four soil types are 1.05 meter deep; their textural characteristics are shown in Table 1. The hydrological characteristics are estimated from clay and sand contents using the Saxton's model (Saxton, 1986). Soil fertility levels are defined from a base "normal" fertility level, which corresponds to the nitrogen, and soil organic matter contents shown in Table 2. Low fertility level is half and high fertility level is 1.5 times the soil organic matter (SOM) and the mineral N (NO_3^- and NH_4^+) contents of the normal fertility level. Water content at the beginning of the simulation (may 15th) is the same for all soil conditions (Table 2). The daily climatic data (solar radiation, minimum and maximum temperatures and rainfall) was collected using Bobo Dioulasso weather station (11°06'N, 4°20'W) Burkina Faso from 1950 to 1985 (except for 1981, 1982 and 1983 years). A reference crop management sequence (RS) is applied for all of the 396 different environmental conditions. This RS is characterized by: emergence date of the 5th of June, plant population of 62500 plants/ha (80 cm between rows; 20 cm between plants), cultivar of the MID season variety type defined in GOSSYM-COMAX User's manual. Three times a year a 100000 bollworms/ha (first-instar of *Helicoverpa armigera*) attack is simulated at these dates: 15/08, 30/08 and 15/09. Nitrogen fertilization is applied twice a year: 44 N/ha at emergence and 23 N/ha on the 20th of July. Simulation period begins on the 15th of May and ends on the 15th of November.

From the base reference management sequence, additional N application (25 kg N/ha in August 8th) and/or the removal of the bollworms attacks, equivalent to a total plant protection on the 15th of August, are introduced in the RS+N, RS+PP and RS+N+PP crop management sequences, respectively. These modification of RS will be used in building-up the decision rules.

In order to quantify the risk associated with input variability, the NAPRA approach was used. The National Pesticide Risk Assessment (NAPRA) is a process developed to evaluate the probability of a quantity of pesticide loss to the environment under various management (Bagdon *et al.*, 1994). The quantity, evaluated for certain number of years of observed or generated weather data and/or soil and management variability, is translated to risk indicators that describe the probability of exceeding a threshold level as a result of the input variability. Additional information on NAPRA application can be found in Engel *et al.* (1998).

Results and Discussion

Average yield and variation coefficients (VC) for the soil conditions are presented in Figure 3. Results show that soil fertility is important for yield independent of soil type. Yield increases of 600 kg/ha from low to normal fertility level and 450 kg/ha from normal to high fertility level were observed. This result affirms the importance of nitrogen as yield limiting factor. For all fertility levels, the variation coefficients are all low due to heavy textured soil. The VC range from 9% to 13% when clay varied from 40% to 10%, respectively. This illustrates the important buffering and regulation role of the soil clay in crop water demand (Table 3).

Yield variability analyses for soil and climatic conditions was conducted and assessed for different risks types using the NAPRA approach. The yield obtained from running the model for the various environmental conditions were ranked in decreasing order and the probability of exceedence for each value is calculated from the rank value as the ratio of the rank value divided by the total number of simulated years. The NAPRA approach allows to quantify the risk for each target yield entry as (1 - probability of exceedence). This risk assessment has to consider the probability of occurrence for each environmental condition involved in the analysis, i.e. each soil type – fertility level – annual weather combination. In this exercise it was assumed that each combination has an equiprobability of occurrence. The analysis for soil types is presented in Figure 1 and for fertility levels in Figure 2. In the case of yield variability analysis for soil types, the variation coefficient appears as a weak indicator for risk assessment. In fact, the higher VC for S_16 (32%) represents a higher risk for that mean. However, according to the yield distribution, it is not the case for high yield levels as illustrated in Figure 1. The probability of exceeding a yield target goal of 2250 kg/ha reaches 0.22 for the S_16 soil type and 0.08 for other soil types. Application of the NAPRA approach to the fertility level yield series of risk assessment is illustrated in Figure 2. As an example, a yield of 1900 kg/ha will be reached with a probability of 0.85 in case of a high fertility level and with a probability of 0.15 for normal fertility level. The second example illustrated corresponds to a yield of 1300 kg/ha, which can be reached with a probability of 0.95 under normal fertility condition and only with a probability of 0.05 under low fertility conditions.

Figure 3 represents the risk for the four crop management sequences. The risk of getting a lower arbitrary yield threshold of 1500 kg/ha decreases from 0.10 for the RS+N+PP crop sequence management to 0.40 for the RS sequence. This means that one year out of 10, the yield will be lower than 1500 kg/ha under the RS+N+PP management sequence, compared to four out of ten years for RS management sequence. Intermediate risk values are observed for RS+PP and

for RS+N management sequences, of 0.37 and 0.28 respectively. Following this probabilistic approach to risk management, our goal was to identify relevant daily decisions criteria to be used to reduce the risk associated with site and weather uncertainties. Our approach to achieve this goal was based on numerical experimentation. In this methodology, we choose to establish decision rules for additional N application on August 8th, and for a complete plant protection on August 15th by removing the three bollworm attacks occurring for RS management sequence. Alternatively, other decision rules based on soil moisture or actual evapotranspiration could have been used. These rules proved to be adequate for our discussion.

Table 4 gives the correlation coefficients between the different crop state variables for the two dates (August 8th and 15th) and the yield for RS management sequence. Figures 4 and 5 represent the scatter plots for the two best fitted crop state variables regressions against the yield on August 8th. These variables were respectively, plant height and fruiting sites number. Figure 6 represents the scatter plots illustrating the regression between green bolls number on August 15th and yield plots for RS with additional N decision rule application. The first decision rule of a 25 N/ha additional application is based on plant height (lower than 50 cm) and fruiting sites number/plant (less than 22). These threshold values are assumed in this exercise to be discriminant for threshold yield value of 1500 kg/ha considered as the farmer's yield target. The second decision rule is based on number of green bolls per plant (less than 4); this threshold value also corresponds to a yield target of 1500 kg/ha.

As expected, through the choice of decision rules building process, application of these decision rules in the case of reference crop management sequence does not have any effect on the risk for yield targets higher than 1600 kg/ha (Figure 7). The risk limitation becomes significant for a yield target of 1500 kg/ha or less. The probability of exceeding 1500 kg/ha increase from 0.60 for RS (4 years out of 10 the yield is lower than 1500 kg/ha) to 0.66 with N decision rule application, and to 0.80 (two years out of 10 the yield remains lower than 1500 kg/ha) with both N and PP decision rules applications (Figure 7 and Table 5).

Table 5 shows the risks for different yield targets, cotton crop management sequences, and decision rules application. The risks are all low (probability of exceedance all high) for low yield target, and additional technical operations (additional N application and plant protection application). Application of decision rule 1 (additional N application) occurs in 30% of the situations encountered with RS management sequence, so that the "cost" (cost of 25 N fertilization in case of decision rule 1 application) of limiting the risk by choosing this strategic decision (DR1) compared to RS management is 0.30 times the cost of additional N application. The same for decision 2 (plant protection) oc-

curs in 38% of the situations encountered with RS+DC1 management sequence, so that the "cost" of decision rule 2 application (DR2) is 0.38 times the cost of plant protection. In the case of RS+N+PP management sequence the cost of N and plant protection are accepted for all the seasons. The "cost" of this strategic decision compared to the RS management sequence is N application cost + plant protection cost (data not shown). The cost evaluation of lowering the risk in decision-making represents a major improvement for technical advice provided to cotton producers.

Summary and Conclusion

A probability based methodology to assess the effect of year-to-year climatic variability, soil and management input on crop response was demonstrated using COTONS®. The methodology allowed for the quantification of the risk associated with these input variability using a systematic and bias-free approach. It also allows the user to identify relevant crop state variables that can be used for short-term better decision making related to crop management. Because of the high cost and time involved in evaluating management practices, these modeling approaches can be effective tools for better decision-making. Due to the significance in their results, the authors recommend this risk-based approach as a way to address decision-making under site and climatic uncertainties.

The COTONS® model was demonstrated as an important research tool for pushing back the limits of classical adaptive research programs. It provides an original tool to analyze the cotton crop response variability, which could not have been assessed with classical enquiries or experimental designs. Under rainfed conditions, the climate remains the main determinant of variability in crop response under a reference crop management sequence. This uncertainty in crop response was simulated by the model and analyzed in terms of risk according to yield targets and crop management sequences. The intermediate crop state variables simulated by the model are used for day-to-day decision rules. This pilot research is an important step before evaluating these decision rules under field conditions. These decisions help reduce the risk of under yield of a target value and have an economic cost associated, which was also presented with these risks.

References

- Bagdon, J.K., Plotkin, S., and Hesketh, E.S. (1994). NAPRA Technology Transfer Overviews: Introduction. USDA Report, Washington D.C.
- Baulch, P.W., Mc Carter, K., Staggenborg, S. and Lambert, J.R. (1995). GOSSYM-COMAX User's Manual. USDA-ES GOSSYM-COMAX Information Unit, 102 Mississippi Technology Center Starkville, MS 39759.
- Engel, B. and Managuerra, H. (1998). A www-

based hydrologic and pesticide movement risk analysis system. *Proceedings of the International Conference on Geospatial Information in Agriculture and Forestry*. 1: 520:527, Lake Buena Vista, FL.

- Jallas, E., Cretenet, M., Sequeira, R., Turner, S., Gerardeaux, E., Martin, P., Jean, J. and Clouvel, P. (1999). COTONS, une nouvelle génération de modèles de simulation des cultures. *Agriculture et Développement*, **22**: 35-46.
- Nibouche, S., Beyo, J., Brévault, T., Cretenet, M., Gozé, E., Jallas, E., Martin, P. and Moussa, A.A., (2002). COTONS-SIMBAD: a tool for establishing cotton bollworm economic damage thresholds, In VII ESA Congress, 15-18 July 2002 Cordoba Spain Book of Proceedings, Francisco J. Villalobos, Luca Testi Ed. p 307-08.
- Saxton, K.E., Rawls, W.J., Romberger, J.S. and Papendick, R. (1986). Estimating generalized soil-water characteristics from texture. *Soil Sci. Soc. Amer. J.*, **50**: 1031-1036.

Table 1. Characteristics for the four soil textural types used in the analysis.

	S_16	S_25	S_34	S_42
Clay %	10	20	30	40
Sand %	60	50	40	20
Ksat cm/h *	63.6	18.8	8.2	6.4
Bulk density *	1.55	1.43	1.35	1.27
% H ₂ O at pF1 *	41.6	46.2	49.1	52.2
% H ₂ O at pF2 *	31.1	35.4	39.4	45.0
% H ₂ O at pF2.5 *	25.8	30.0	34.5	41.5
% H ₂ O at pF3 *	20.5	24.6	29.6	37.9
% H ₂ O at pF4.2 *	8.9	12.6	16.8	22.2

* Estimated by Saxton's model

Table2. Soil initial conditions (on May 15th) used in COTONS® simulations.

Normal fertility level				
Depth	N_NO ₃ ⁻ (kg/ha)	N_NH ₄ ⁺ (kg/ha)	SOM (%)	H ₂ O (%)
0-15 cm	19.18	2.13	0.62	80
15-30 cm	14.58	1.57	0.48	50
30-45 cm	14.14	1.57	0.46	50
45-60 cm	11.44	1.23	0.42	40
60-75 cm	9.76	1.12	0.37	40
75-90 cm	8.30	0.90	0.31	40
90-105 cm	6.84	0.79	0.25	30

Table 3. Average yield and variation coefficients for the four soil conditions.

Fertility levels								
	Low		Normal		High		Means	
	kg/ha	V.C.%	kg/ha	V.C.%	kg/ha	V.C.%	kg/ha	V.C. %
S16	1083	12.61	1789	13.72	2288	12.84	1720	31.89
S25	1033	12.55	1604	14.93	2053	12.82	1563	30.21
S34	1042	11.55	1622	12.65	2063	11.51	1575	29.33
S42	1109	8.89	1695	9.17	2131	8.10	1645	27.03

Table 4. Correlation coefficients between final yield and selected crop state variables used for the decision rules on August 8th and August 15th.

	August 8 th	August 15 th
Plant height	0.88	0.79
Main stem node number	0.81	0.75
Plant leaf area	0.87	0.76
Node above white flower	0.80	0.69
Plant leaf number	0.86	0.78
Fruiting sites number	0.88	0.80
Squares number	0.87	0.71
Green bolls number	0.81	0.81
Abscised sites number	0.88	0.62

Table 5. Probability of exceedance for different yield targets and the four crop management sequences along with associated cost.

Yield target	Probability of exceedance			
	RS	RS+DR1	RS+DR1+DR2	RS+N ¹ +PP ²
1500 kg/ha	0.60	0.66	0.80	0.90
1400 kg/ha	0.63	0.76	0.87	0.97
1300 kg/ha	0.67	0.87	0.95	0.99
1200 kg/ha	0.71	0.93	0.97	1.00
"Associated Cost"	0	0.3N	0.3N+0.38PP	N+PP

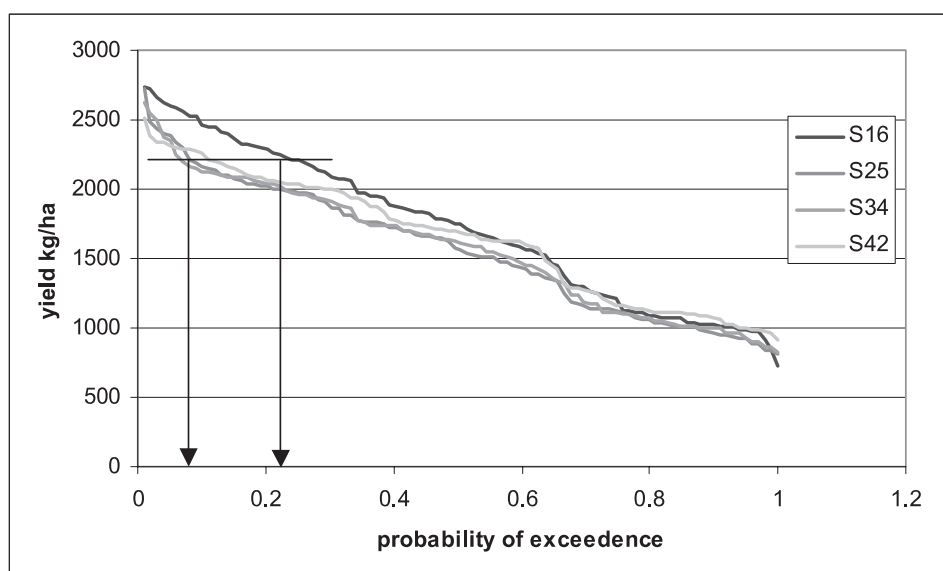
¹ N cost of extra 25N/ha application.² PP cost of full plant protection from August 15th.**Figure 1.** Risk analysis for the four soil types using the probability of exceedance approach.

Figure 2.
Risk analysis
for the three
fertility levels.

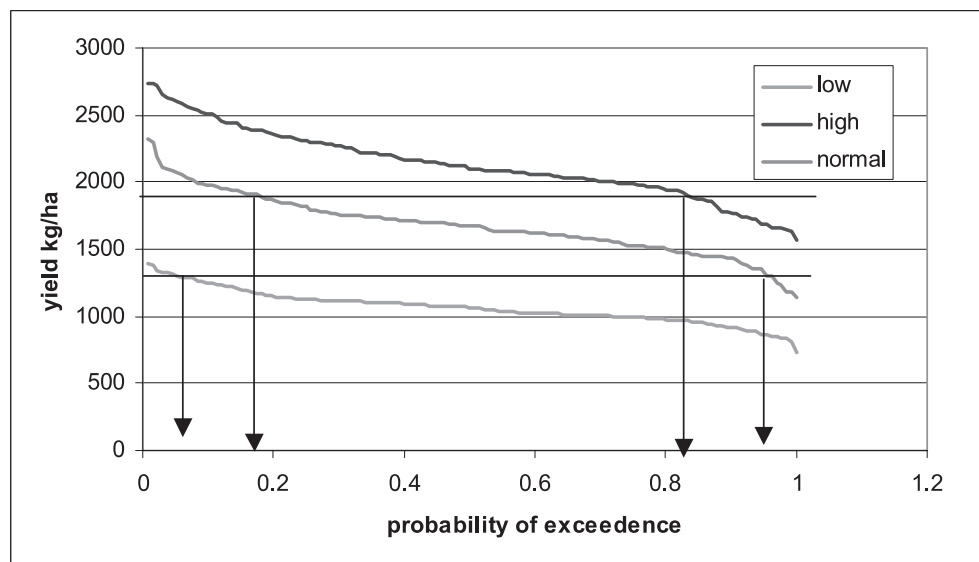


Figure 3.
Risk analysis
for the four
crop manage-
ment se-
quences.

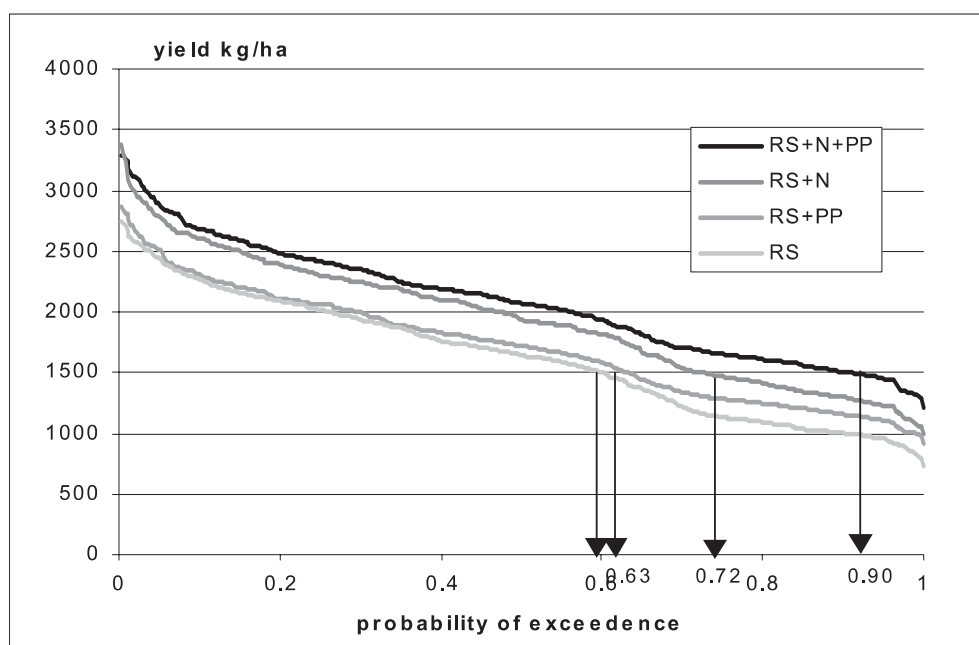


Figure 4.
Plant height
on August 8th
and crop yield
correlation for
RS manage-
ment se-
quence.

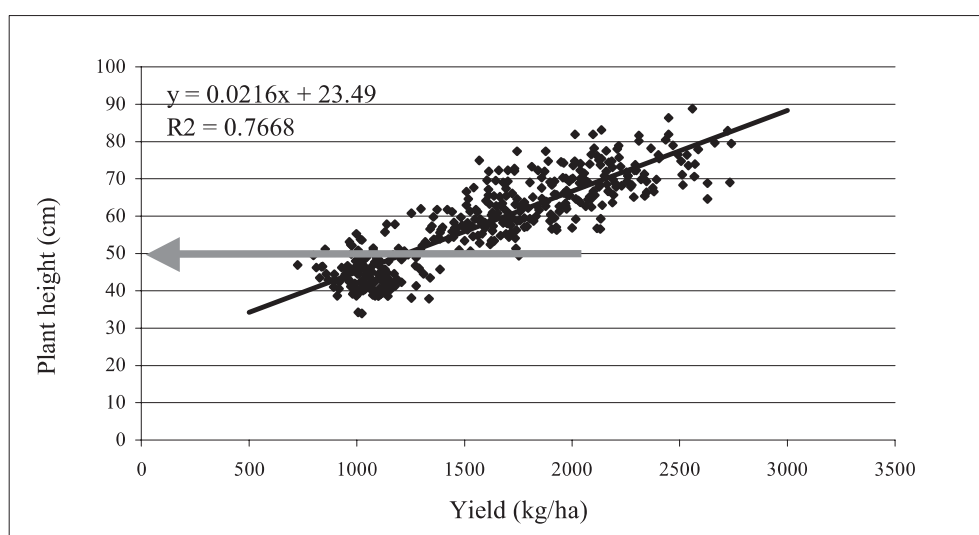


Figure 5.
Number of
fruiting sites
on August 8th
and crop yield
correlation for
RS manage-
ment se-
quence.

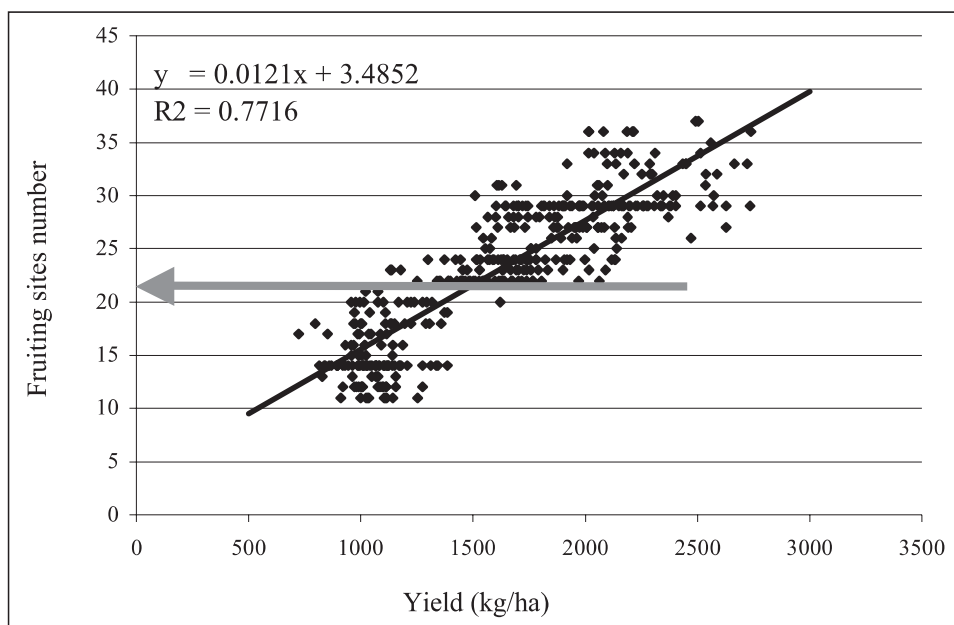


Figure 6.
Number of
green bolls on
August 15th
and yield
correlation.

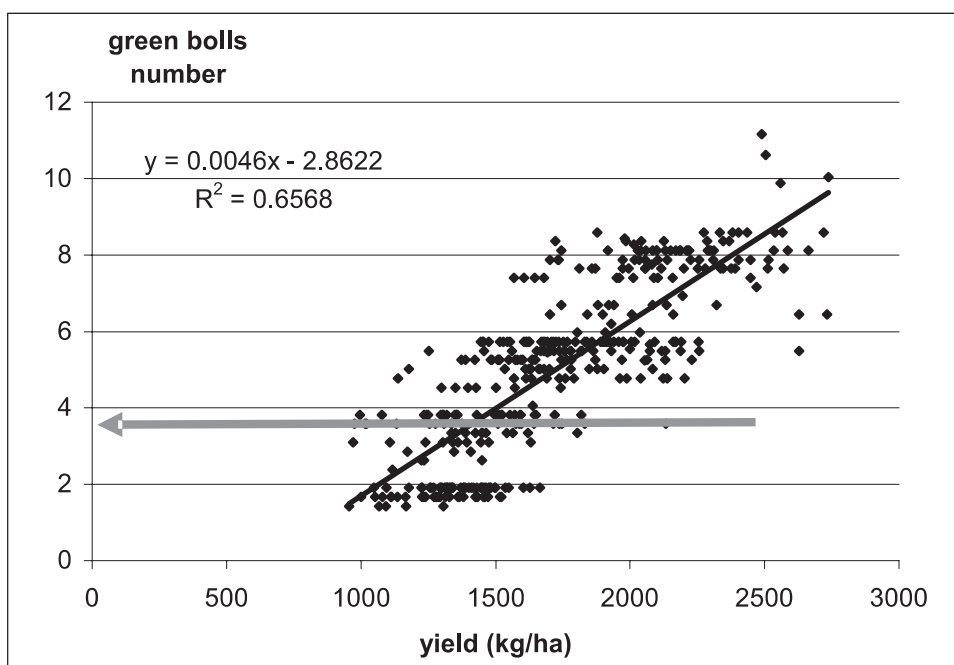


Figure 7.
Risk limitations
according to
decision rules
application
(specific risk
values for
1500 kg/ha
yield target).

